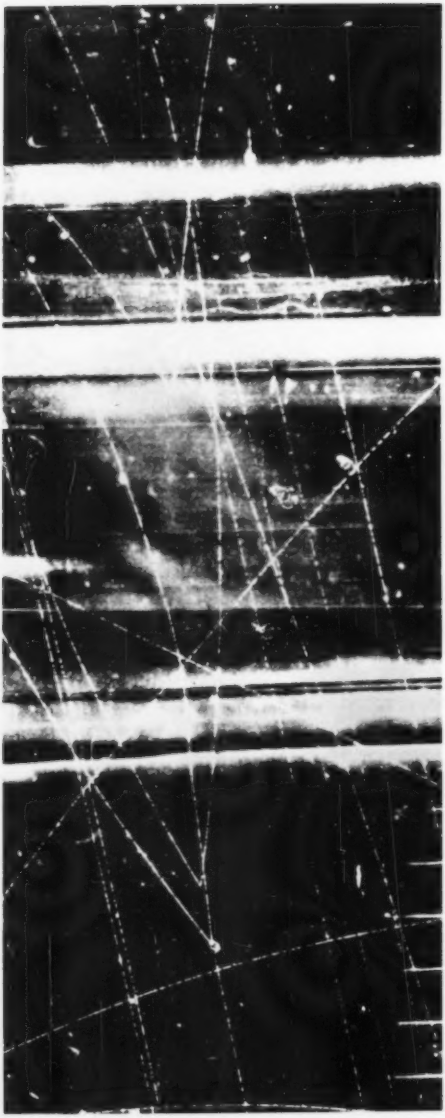
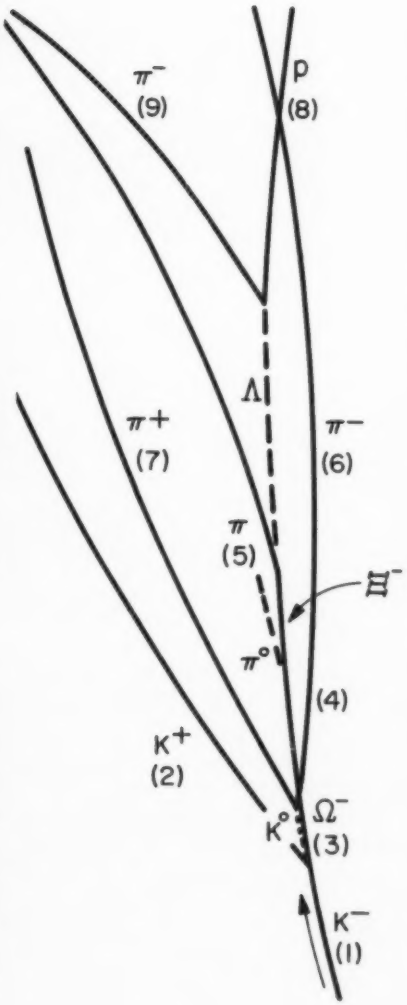
NAVAL RESEARCH

REVIEWS

FEBRUARY 1965





The 1000-foot-diameter radio direction-finding system at the University of Illinois.

Large, Precise Radio Direction-Finding System Developed for Navy

One of the world's largest and most precise radio direction-finding systems has been developed by the University of Illinois under a contract with the Office of Naval Research. The system can determine the direction from which a signal arrives within a one-half degree of accuracy.

Currently, the system is being used to acquire information concerning the properties of the ionosphere. In particular, it is hoped to understand the deviousness of the path of a radio signal through the ionosphere. Such factors as sun spots and moment-to-moment variations in the ionosphere often bend the signal by several degrees and, in extreme cases, by as much as 90 degrees, which makes it difficult to determine the location of the signal's origin.

Professor Edgar C. Hayden, who is in charge of the project, has reported that transmissions from Washington, D.C., have arrived at Illinois from the apparent direction of the North Pole. Deviations of 2 or 3 degrees are quite common, and variations of 30 degrees are not unusual.

The Illinois radio direction-finding system is an enlargement and improvement of the Wullenweber finder, which was developed by the Germans during World War II. Since 1946, Illinois engineers have greatly increased receiver sensitivity and directional accuracy, markedly reduced the effect of interfering stations on the same operating frequency, and developed the system as a research tool for probing the ionosphere. During this period, support has been provided by both ONR and the Bureau of Ships.

— Continued on Page 14

Status and Potential of Research Ballooning

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The earth's atmosphere, because of its anomalous, uncontrollable, and unpredictable variability, poses difficult problems in the pursuit of scientific and operational objectives in that medium. These problems are compounded by the fact that the atmosphere is neither isotropic nor homogeneous. Within certain limits, corrections can be made to overcome many of the problems. Beyond those limits, however, reliable corrections cannot be made. As a matter of fact, the most serious problem now existing in the operation of modern instrumentation and systems in the atmosphere is the uncertainty of the atmospheric effects. It is rather paradoxical, therefore, that many complex systems are carried to the operational evaluation stage before adequate thought is given to atmospheric effects. At that stage, the only recourse left is to try to minimize the uncertainties, which means prolonged evaluation testing.

Although our sensible atmosphere extends hundreds and perhaps thousands of miles into space, 50 percent of its mass is concentrated between sea level and an altitude of 3-1/2 miles; 90 percent is below an altitude of 10 miles; 99 percent is below 20 miles; and 99.9 percent is below 30 miles. It is apparent, then, that by utilizing vehicles capable of "leap-frogging" the main mass of our atmosphere, scientists can avoid most of the undesirable and/or undeterminable effects of the atmosphere on their experiments.

The concentration of practically all of the earth's sensible atmosphere within a relatively shallow layer makes the Skyhook balloon an attractive tool for conducting various types of scientific experiments for long periods of time in near-space conditions at almost any geographical location. The capability of the Skyhook balloon has been so highly regarded since its first use about 17 years ago that balloon development has been unable to keep pace with the rapid, continuous increase in scientific requirements. Balloon sizes and payload weights have increased by about two orders of magnitude. Balloons have swelled in volume from 10,000 to over 1,000,000 cubic feet. Scientific payloads have jumped in weight from less than 100 pounds to more than 10,000 pounds. And altitude requirements have been extended from around 100,000 feet to at least 150,000 feet.

As a result of these constantly increasing scientific demands, balloon capabilities have been taxed to the point that flight reliability is now approaching 50 percent. The high probability of loss or excessive damage to current sophisticated scientific payloads is becoming of greater concern to the scientist, and interest is increasing in obtaining balloons having a greater reliability. The mounting failure rate of balloons fabricated of polyethylene, the material most commonly used in the manufacture of Skyhook ballons, is related directly to increasing balloon size. The low tensile strength of polyethylene provides no safety factor for concentrated stresses induced by the unsymmetrical development of the gas bubble during the ascent of the balloon. Although the exact causes of the increased failure rate have not been determined, the low strength of polyethylene appears to be the most important factor precluding any significant increase in the reliability of balloons made of this material.

Polyethylene films of which Skyhook balloons are now being fabricated were developed originally for commercial purposes. Since the portion of these films used for balloon fabrication is extremely small compared with the total quantity used by industry, film extruding companies have no great incentive to improve film characteristics for balloon applications. Other films, such as Mylar and polypropylene, have been examined for balloon fabrication because of their high tensile strength. Unfortunately, these films are more difficult to seal and have very low tear resistance. A reinforced Mylar film has been developed, however, and is now in use for sophisticated flights in which the scientific payloads and scientific objectives justify the much higher cost of such balloons; the Stratoscope II balloon-borne telescope system exemplifies such a requirement. Extremely thin polyethylene film, approaching 1/10,000 of an inch in thickness, reinforced with nylon filaments, is being tested as a balloon material to carry moderately heavy scientific payloads (less than 500 pounds) to altitudes of 140,000-150,000 feet. Composite films of polyethylene and polypropylene laminates also are being tested and show great promise for improved reliability at economical costs. With the effort being made currently by all supporters of scientific ballooning to improve the capabilities of balloons, it can be assumed that in the future these vehicles will reach higher altitudes and carry more weight with greater reliability than they do at present. By the same token, it can be assumed that increasingly stringent scientific requirements will demand continuing developmental effort to insure the availability of reliable balloon systems.

The capability of Skyhook ballons was recognized quickly from operational as well as scientific aspects after the first ONR-sponsored flights of those balloons many years ago.

The Air Force now provides complete balloon launching, tracking, controlling, data collection, and recovery facilities for its in-house high-altitude research program, for its contractors, and for other organizations having programs of interest to the Air Force. Most of this service's programmed balloon flights are launched from Holloman Air Force Base, New Mexico, or Chico Municipal Airport, California. In addition, the Air Force has developed a mobile launch capability which permits balloon operation anywhere in the world.

The Weather Bureau carries out a continuing balloon program for the sampling of particulate matter in the atmosphere. Under this program, flights are launched at San Angelo, Texas, by the Weather Bureau, and at Mildura, Australia, by the Australian Department of Supply. Four samples of atmospheric particulate matter are required each month. Because of the failure rate of current balloons, eight or ten flights frequently must be made to insure that the four samples are obtained.

The National Center for Atmospheric Research (NCAR) has established a Balloon Flight Facility at Palestine, Texas, which has been in operation now for about two years. Complete launch, data-collection, control, tracking, and recovery facilities are available to civilian scientists and government agencies. Plans call for construction of a huge balloon-inflation structure to permit more orderly launch schedules to be kept. NCAR also operates a more limited balloon flight facility at Page, Arizona. This location is ideal for winter-time flights because of the extremely light ground winds and favorable float trajectories of that area. Such conditions permit static vertical launches, which are desirable for large balloons and scientific payloads because of the delicate handling and release operations involved. NCAR is currently managing a series of scientific balloon flights to be conducted from Hyderabad, India, in March 1965, in conjunction with the International Quiet Sun Year (IQSY).

The Office of Naval Research provides scientific balloon flight services for scientists sponsored by several agencies. Scientific objectives vary from astronomical observations conducted with remotely controlled balloon-borne telescopes to studies of galactic and solar particles and their atmospheric interactions utilizing nuclear emulsions, spark chambers, and scintillation counters. A large percentage of the ONR balloon flights are conducted at high northern latitudes because of the deeper penetration of high-energy particles there. Balloons are launched from the Fort Churchill Research Range, and the scientific payloads are recovered in the region around Lake Athabaska, Saskatchewan, Canada. Scientific flights for which locations are not critical are conducted from either Air Force or NCAR facilities.

Continuous coordination and liaison is maintained between the various scientific ballooning groups through visits, panels, and technical symposia.

Balloon Launch and Recovery of a Scientific Payload

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1. A Skyhook balloon is inflated with helium in preparation for launching of instrument package on journey into stratosphere.
2. After reaching its assigned altitude and after completion of experiments, the scientific package separates automatically from the balloon and descends by parachute. Aircraft track its path to earth.
3. The payload, which dropped undamaged into a forest, is located by recovery team flown to the site by helicopter.
4. The package is loaded on helicopter for removal to the shore of a nearby lake.
5. At the lake shore, the package is loaded aboard a plane equipped with pontoons for shipment back to base of operations.

Pictures numbered 2-5 were taken in Saskatchewan, Canada, during the recovery of a payload launched by Skyhook balloon from Fort Churchill. Picture number 1, depicting the launch in this series, was taken at Sioux Falls, South Dakota, during Skyhook balloon operations in that region.

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Research balloon technology is beset currently by material limitations and reliability problems. New and improved balloon materials are within the state of the art, however, and require only moderate funds to exploit. Higher balloon costs will no doubt result, but the unique and exclusive capability of Skyhook balloons to remain at high altitudes for long periods of time is so well established that their use for scientific and operational objectives cannot help but increase. With the current balloon capabilities, a typical ONR field operation, considering all needs, costs about $100 per pound of scientific payload carried to an altitude of about 130,000 feet. What other system designed to meet scientific and operational objectives in the atmosphere provides so much for so little?

CAPT Thomas B. Owen, USN

Change of Command at NRL

CAPT Thomas B. Owen, USN, succeeded CAPT Bradley F. Bennett, USN, as director of the Naval Research Laboratory on February 5. CAPT Owen, formerly the Laboratory's director of support services, is a combat veteran who served aboard ships of the fleet from early 1941 until 1945. He is also the holder of a doctorate degree in chemistry, which he received from Cornell University. CAPT Bennett, the Laboratory's twentieth director, has retired from the Navy after 30 years of service.

The new director of NRL received the Silver Star Medal for action in the Battle of Tassafaronga. His ship, the heavy cruiser USS NORTHAMPTON, was sunk in the battle. About two years later, another ship he was serving on, the destroyer USS BUSH, was sunk during a kamikaze attack off Okinawa.

After the war, CAPT Owen was assigned to the U.S. Naval Postgraduate School for graduate study in electronic engineering. In 1947, he was selected by the Navy to attend Cornell University, where he received his doctorate degree in 1950. In 1951, he completed a year of postdoctoral work at the University of Amsterdam, the Netherlands. He completed the resident course at the Industrial College of the Armed Forces at Fort McNair, Washington, D.C., in 1962.

Other of his assignments include duty with the Office of Naval Research, the Long Beach Naval Shipyard, the Bureau of Ships, and the Deputy Director of Defense Research and Engineering.

Before coming to the Naval Research Laboratory as director of support services early in 1963, CAPT Owen was on temporary duty with the Assistant Secretary of the Navy for Research and Development.

In addition to the Silver Star, CAPT Owen holds the Bronze Star, the Asiatic-Pacific Campaign Medal with 12 battle stars, the Philippine Liberation Medal with one star, the Navy Unit Commendation Ribbon, and others.

Communication by Voice

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Communication by voice is relatively slow, permitting, at best, only from five to seven syllables to be uttered per second. It is readily masked by other sounds. It is restricted to listeners with normal or near normal hearing and to talkers and listeners who have a common language. Because of these conditions, much can go wrong with the transmission of messages by voice. Nevertheless, such delivery remains at the center of military communication—in discussions that involve policy, in bringing action to bear on observed targets, in coordinating team effort, and in reporting results. If the voice carrying the message is garbled, the communication will be wasteful, and it could have even disastrous consequences.

In the context of this discussion, which concerns an effort to achieve faultless voice communication, the clear message and the intelligible one are synonymous. They are messages that might be either written or repeated verbatim by a listener. For voice communication to be perfect, this property of the message must be assured even before the message is spoken. Thus, in providing for faultless voice communication in the Navy and elesewhere, it is crucial to select in advance, on the basis of demonstrated performance, (a) communication equipment of high intelligibility, (b) messages of proved intelligibility, (c) talkers who characteristically speak intelligibly, and (d) listeners who are skillful in receiving spoken messages.

Our effort to achieve faultless voice transmission has required, on the one hand, a group of speech and hearing specialists, whose task has been to measure the intelligibility of spoken words, and, on the other hand, various groups of human subjects, whose speech and hearing was to be analyzed.

A team of subjects consists typically of a dozen men. One day they compare alternative transmitters; another day, receivers. In rotation, they read lists of English words, 50 words to a list. For example, the first word might be *game*; the second word, *walk*; and the last word, *fall*. The items are spaced at 10-second intervals. As one member reads, the remaining 11 men write what they hear. The talkers normally speak into microphones, and the listeners hear through headsets. A continuous noise simulating the sound of an air-conditioning ventilator or the sounds heard in the cockpit of an aircraft is introduced into the communication line along with the verbal messages.

By following this procedure, at least four experimental findings have emerged:

- Clear evidence that one set of voice-communication equipment is superior to another in terms of transmitting messages correctly.
- A scaling of words in terms of receptability. For example, *football* is heard correctly by 95 percent of the listeners; *faith*, the least readily identified word, is heard correctly by 5 percent of the listeners. The other 598 words fall between *football* and *faith* on a recognition scale. The need for such a scaling of words goes back many years; during World War II, for example, the Armed Services requested lists of intelligible words and lists of words of high contrast—that is, pairs of words that could not be confused—for the voice transmission of military messages.
- Jones is 75 percent intelligible; Smith, 30 percent intelligible; the remaining 10 speakers are ranked between these extremes. Obviously, Jones is well suited to fill the talker's spot, and the phones should not be entrusted to Smith.
- Brown identifies 71 percent of the 550 words that he hears; Low identifies 37 percent. The remaining listeners fall between these extremes. Here, too, the differences provide a basis for selecting members of a communication team—that is, in terms of listening ability.

The last three findings are discussed in this article.

The Understandability of Words

There is a lawfulness about the intelligibility of messages. The intelligible word usually has more sounds and syllables than the less intelligible word. It is one that is spoken often rather than rarely. With respect to its phonetic composition, a word is the more intelligible for containing particular sounds; for example, the first sounds of the following words (isolate the first sound, which may be either a vowel or a consonant): *it, else, at, oil, out, but, key, go, show, chew, jump, no, me;* it is the less intelligible for including the initial sounds of *all, oak, pal, fee, theme, hill,* and *like.*

The garbled word is received poorly and may lead to wrong responses. Such misidentifications do not occur at random. Different listeners tend to make the same mistakes somewhat independently of who is speaking. Such behavior suggests that the listeners learn to hear speech sounds in a set way. However, in identifying words from acoustic clues, every listener makes judgments that come directly from his own experience. He originates his own errors.

One fortunate consequence of making "errors-in-common" is that the most frequent mistakes (wrong words) can be printed along with the

right word to set up a multiple-choice answer form for measuring intelligibility. A listener only needs to indicate which of the printed words he believes he hears. Machine scoring follows, and the tiring and unreliable scanning and marking--akin to a teacher's scoring of spelling papers, but expanded manifold--can be avoided. A careful check of the responses to *grew,* spoken and heard many times, might show that while 50 percent of the listeners heard it correctly, 20 percent of their peers wrote *groove,* another 10 percent wrote *glue;* and 6 percent wrote *group.* The second most frequent error, *glue,* is made one-half as frequently as the first; the ratio of the third to the second error response is greater, 0.6. If these four words then are made optional choices on a multiple-choice answer form, the ratios among the errors continue to obtain. (See Figure 1.)

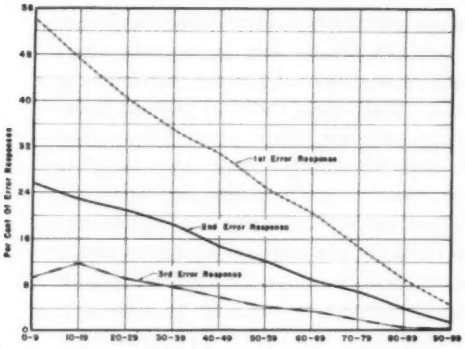

Figure 1 — Graph showing relationship of errors made by groups of individuals tested in their understanding of spoken words. "1st Error Response" refers to word most commonly substituted for correct work; "2nd Error Response," to next commonly substituted word; and "3rd Error Response," to third most commonly substituted word. Irrespective of the intelligibility of words, the value of the second most frequent error response is one half the value of the most frequent error response, and the ratio of the third to the second is greater than one half.

Another lawfulness emerges from measurements of intelligibility: the recognizability of a word is somewhat predictable. Obviously, the intelligibility of the individual sounds of speech can be computed. Consider the example given in the preceding paragraph: *grew* (50 percent), *groove* (20 percent), *glue* (10 percent), *group* (6 percent), and infrequent, scattered responses (14 percent). The four most frequent responses to the stimulus *grew* contain an initial sound [g] and the vowel sound [u]; thus, both of these sounds are at least 86 percent intelligible. All of the sounds of *grew* are in *groove* and some are in each of the other two words. If the stimulus were a nonsense syllable, the relation between the single sounds and the syllable would be simple: the joint product of the intelligibility of the separate sounds would serve as a predictor of the intelligibility of the syllable. With words, such an analysis leads to the unrealistic outcome that longer words are predicted to be less intelligible than shorter ones. What is actually the case is that the intelligibility of a word can be equated reasonably well with the product of the intelligibility values of its first two sounds. This does not mean that other

sounds of the word contribute nothing to its intelligibility or that all of the potential contribution toward intelligibility, carried in the first two sounds, is utilized.

The identification and misidentification of the word have been related in these paragraphs to the phonetic content of the word, particularly, and to the word's length and probability of occurrence. However, other factors are involved. In the circumstance of the preceding paragraph, if one should hear the message "the word is *grew*, not *groove*" the combination would yield approximately 70 percent correct identification; that is, 50 percent (grew) plus 20 percent (groove). Possibly, if the message were "the word is *grew*, not *groove*, and not *glue*" the reception would be approximately 80 percent correct.

Another way to improve the intelligibility of a word is to put it in context. The word then becomes more than the sum of its phonemes, and its length is of relatively little consequence. How much improvement? How much context? By context, we do not necessarily mean discourse or sentences. Meaningful sentences, of course, increase the intelligibility of the member words. "Mary *grew* radishes" would never be misinterpreted as "Mary *groove* radishes." But, even a low-order approximation of English syntax provides sufficient context to improve intelligibility. For example, if the word preceding and the word following a test item "fit" the test item, that item is more intelligible than it would be in isolation, irrespective of the nonsensical character of the group of words. Thus *grew* is progressively more intelligible in these successive messages, which were presented at random to panels of listeners: (1) "*grew*"; (2) "*grew* not *groove*"; (3) "were they *grew* some little"; and (4) "little Mary *grew* some radishes."

Much lawfulness contributes to the listeners' correct and incorrect identifications of verbal material.

The Communicators and Their Language

The 12-member crew from which measures of intelligibility were obtained was described as serving rotationally as speakers and listeners. Each man's functions were both oral and aural, comparable to those of both the sender and receiver of a communication team. Importantly, the two functions are closely related. The data we obtained for young foreigners who are speaking English in an American university provide a convincing illustration. Although such students are very carefully selected for enrollment in American universities, there is marked disparity among them in their ability to cope with English, both in speaking and listening. The following experiment makes this disparity evident.

Twenty-four Hindi, 24 Spanish, and 24 Japanese speaking students in an American university were tested for listening comprehension.

Based on this test, each group was divided into upper and lower halves, and the performance of the two subgroups was observed and compared. All of the students read multiple-choice intelligibility tests on which test words were arranged in groups of three, preceded by an identifying phrase, such as "Number one airport bark tassel," ("Number one" being the identifying phrase and "airport," "bark," and "tassel" being the test items). A group of words arranged in this fashion was spoken as though it were a continuous sentence, one "sentence" each 10-seconds. All of the acoustic material was recorded. Subsequently, three sets of measures were obtained from the recordings, two from responses of panels of American listeners and one from a meter for detecting and measuring the durations of pauses.

Statistical analysis of the measures revealed the following facts: (1) In each language group, the half consisting of the better listeners was also the half consisting of the more intelligible speakers. (2) In each language group, the poorer listeners exhibited more foreign dialect than the better speakers. (3) In each language group, the better listeners, when speaking, spent more time making the sounds of speech and less time pausing than did the poorer listeners. The interdependence of speaking and listening abilities demonstrated in this experiment is in keeping with a theory held currently which relates speech perception to speech production. Essentially, according to this theory, called the motor-behavior theory, the sounds which a person does not readily produce orally, he cannot readily perceive aurally, and vice versa.

According to our present understanding, there seems to be little relationship between the motor-behavior theory and the idea that there is a human repository for vocabulary and language structure. In order to support his own theories of information transfer, communications-theorist Claude Shannon developed a method applicable to tests of the motor-behavior theory in language. An early modification of his letter-predicting technique permits the investigator to provide the correct response in the event the experimental subject gives an incorrect one. The subject may progress at a fairly rapid pace in the following manner:

The predictor (subject) might say...	The investigator would say...
1. *t* (he might be thinking of *the*)	wrong, *h*
2. *a* (he now knows the first letter is *h*; he is thinking possibly of *half*)	wrong, *e*
3. space (he assumes the word is *he*)	right
4. *a*	wrong, *l*
5. *e* (he is thinking of *let*)	wrong, *o*

6. *s* (he is thinking of *lost*)	right
7. *t*	right
8. space	right
9. *h* (he is thinking of *his*)	wrong, *t*
10. *h*	right
11. *e*	right
12. space	right, etc.

The outcome of the letter-predicting procedure would seem to relate to one's knowledge of English vocabulary and syntax.

In one test utilizing this technique, three groups of students were asked to predict four English phrases and sentences: 25 native students in an American university, 25 Italian students who were sufficiently confident of their mastery of English that they had applied for scholarships to American universities, and 25 Yugoslavian students who had studied English for 8-12 years in school. The results indicate that a relatively small advantage was held by the students to whom English was vernacular. Indeed, similarities of the letter-predicting responses of the three groups are striking, not at all in keeping with the disparities that are common in the aural perception and oral production of American speech in such groups of students. (See Figure 2.)

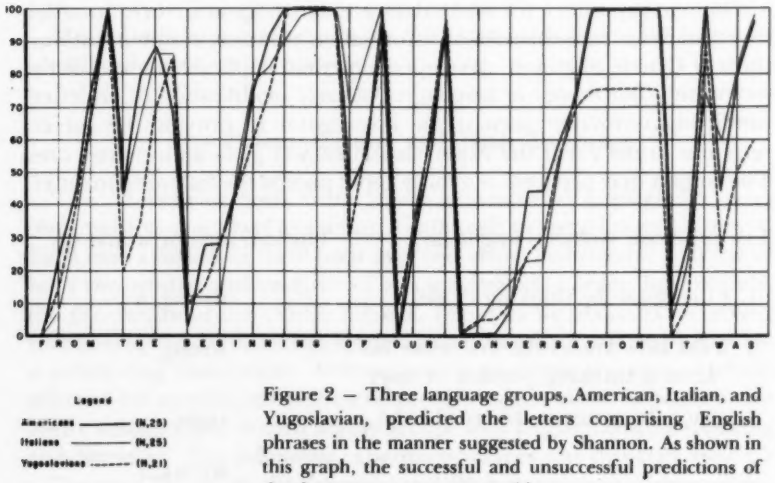

Figure 2 — Three language groups, American, Italian, and Yugoslavian, predicted the letters comprising English phrases in the manner suggested by Shannon. As shown in this graph, the successful and unsuccessful predictions of the three groups are comparable.

Improving the Operators

Could the flaws of the communication network in which a 12-man testing crew operates be mended? The misunderstanding of words was attributed to the code, the talker, and the listener, not to any weaknesses in the line. Obviously, improvements are feasible. A relatively intelligible code or language would exploit the better part of phonetic intelligibility, and it would utilize context and probable words and avoid bizarre signals and rare words.

Training that focuses upon intelligibility elicits in the second or third session a common-sense behavior that was learned in childhood and is often drawn upon in later life after repeated failures in communication: loud talk and clear articulation. Importantly, a person can be his own teacher of intelligibility. Utilizing the now familiar multiple-choice intelligibility test phrase, "Number one airport bark tassel," young Mr. Mumbler sits in a small booth, faces a panel, and reads aloud *number one airport bark tassel,* which appears in an open window above a tele prompter. Mumbler has scarcely finished reading when he hears a similar message, *number ten group flicker beef.* A second window above the teleprompter presents visually three columns with four words in each and permits the subject to select, by pushing an appropriate button, one word from *group, troop, coop, fruit;* one word from *flicker, quicker, slicker, liquor;* and one word from *beef, beast, beat, beam.* If he selects the correct responses, a numerical score, cumulative for the entire exercise, flashes in front of him. The machine is programmed to present one frame of verbal material after another. Successive lights prompt the subject to push a sequence of buttons that brings into view new material for reading and that is synchronized with the recordings of phrases with which he was tested earlier. (See Figure 3.)

Mumbler hears and talks alternately. The words that he hears now are the ones he spoke a few moments ago, *number one airport bark tassel,* and the voice is his. Time and preoccupation have taken a toll: his memory helps him very little, if any. Mumbler's articulation is so poor he must now almost guess what he just heard himself say from a recording that was made only four or five minutes previously. Then he presses a button for a score; he was wrong! He cannot understand himself! This is challenging. He draws upon his lifelong experience in talking and listening; he talks louder and clearer. He tends to improve in his ability to understand himself. He is talking better. It could be that he is only paying attention and memorizing what he says in order to use this memorized version when the time comes. But we know that is not what has happened, because a recorder was put into the system, and Mumbler's recorded speech was played back to a panel of listeners. They, too, recognized the latter part of his exercise to be more intelligible than the earlier part.

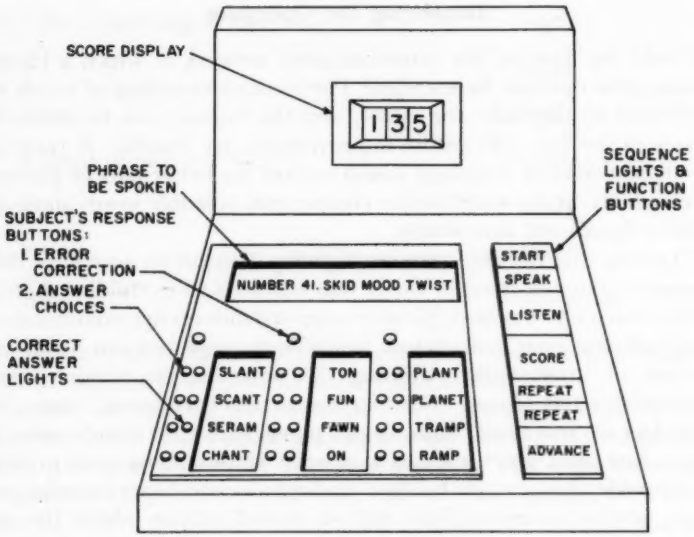

Figure 3 — The panel of a device for self instruction in intelligibility.

The ability of men to speak and hear words intelligibly upon the first utterance of the words, particularly when the men are transmitting or receiving Naval or other military messages, is obviously vital. The experimental procedures discussed in this article reveal not only the weaknesses of voice communication, but also techniques which might be utilized to overcome them. Through the careful engineering of messages and the training of oral-aural communicators, first-time high intelligibility can be achieved. Especially important to the training sessions conducted to achieve high intelligibility is the provision of a means whereby the communicators learn to recognize their own inadequacies so that they can help themselves to become intelligible.

—Continued from front (inside) cover

The present system covers a circular area nearly 1,000 feet in diameter. Around the perimeter of this area is a 65-foot-high circular screen composed of 960 vertical wires. The screen is supported by 120 poles of the same height. Surrounding the screen is a circle of 120 vertical antennas, each 16 feet high, connected by individual cables to a radio receiver inside the circle.

This instrument can scan the horizon as many as 900 times a minute. Information is displayed on a cathode-ray tube similar to a radar scope. In addition, the directional information on radio signals can be transferred to teletype tape for transmission to distant points for analysis by a computer.

Some Experiments in Marine Biotelemetry

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Tucson, Arizona

The dolphin, an air-breathing marine mammal, is an excellent subject for specialized investigations of physiological responses which occur in mammals, including man, in the marine environment. However, the techniques and equipment necessary for measuring these responses, particularly at considerable ocean depths and pressures, are not available at present. For this reason, Professor Baldwin is attempting to devise telemetering devices which convey physiological information from the subjects to observers at the surface. His studies, some of which are described in this article, have been supported by the Office of Naval Research, the Army Research Office, and the Air Force Office of Scientific Research.

In the summer of 1964, Kenneth S. Norris of the University of California at Los Angeles released two mature dolphins in the open ocean in order to conduct physiological and hydrodynamic studies of these mammals, which were trained to return from their natural environment on command of the investigator. The event represents a pioneering effort to obtain detailed information on the physiology and behavior of marine animals with the aid of telemetric instruments.

Norris' experiment was undertaken to determine the maximum swimming velocity of dolphins in both rough and quiet water and the depth to which these air-breathing mammals can dive. While the results have yet to be interpreted fully, the inferences are that a single dolphin, *Tursiops gilli*, attained swimming velocities of about 15 knots in both the open ocean and in quiet water without causing wave action. Another species, *Steno bredanensis*, dove to a depth of 125 feet before the test was interrupted by the arrival of several large sharks. Perhaps this short experience highlights both the potential of such work and our ignorance of the difficulties we face.

Marine biotelemetry offers the hope that observations of the physiological ecology of sea animals may be made accurately in realms that are beyond the range of the human senses. While the link between the observer and the observed animal is not as tenuous as it is in many space experiments, the medium of the deep sea is almost as foreign to our knowledge, at this time, as the medium of space. Nevertheless, exciting progress has been made in recent years in obtaining first-hand observations of living creatures in the ocean depths—for example, by the building of protective "cocoons" around observers and the lowering

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of elaborate instruments. Many such procedures are still expensive or difficult to carry out successfully, however, so alternative methods of obtaining the information are being studied. One of these approaches involves the use, as "observers," of certain marine animals whose physiology and sensory skills are comparable to those of the human. It should be possible to monitor remotely the physiology of an air-breathing marine animal, such as the dolphin, and develop an understanding of its reactions and adaptation to high pressure and cold temperature in the real environment beyond the laboratory.

The study of other marine animals offers interesting possibilities, also, and should produce many new insights into the ways those animals have solved problems that are subjects of current research interest. A few of the more obvious questions biologists are pondering are how do whales extract fresh water from saline water for drinking, how do many migratory animals navigate in the trackless regions of the sea, and how do seals and whales solve the problems associated with deep diving. The sensory skills of marine life are extremely varied, and their study should teach us much about visualization without light and sight.

The Sensory Systems Laboratory, Tucson, Arizona, has been concerned with the development of experimental techniques in which instruments are attached to freely moving aquatic animals. A system for injecting olfactory attractants (fish fluids) into the nostrils of a shark was developed and tested in the summer of 1963 at the Cape Haze Marine Laboratory, Sarasota, Florida. The objective was to determine the ability of the nurse shark, *Ginglymostoma cirratum*, to detect weak stimulants against a natural background, and to learn whether this animal employs its nostrils to localize the source of an odor. Two hypodermic syringes were mounted on the body of a shark in such a way as to inject the test fluid into its nostrils at a known flow rate and at a predetermined concentration. The first ultrasonic transmitter applied to this experiment was suitable for remote off-on control of the syringes in relatively small enclosures or ponds. More recently, small battery-operated transmitters have been constructed that permit control to be effected at ranges in excess of 1,000 feet in the open ocean.

A photograph on page 19 shows the receiver portion of the system being mounted on a large nurse shark in the initial feasibility studies. In this case, the receiver and syringe assembly are being attached to the body surface with quick-setting adhesive. Fortunately, the nurse shark is relatively lethargic and survives for considerable time when removed from sea water.

Recent experiments with ultrasonic telemetry have led to the ability to record electrocardiogram (EKG) signals from freely swimming mammals. Records have been obtained from the harbour porpoise (*Phocaena phocaena*), the Greenland seal (*Phoca groendlandica*), the Pacific white sided dolphin (*Lagenorhynchus obliquidens*), the pilot whale (*Globocephala*

malaena), and man. A photograph on page 18 shows an EKG transmitter that has been attached, by an elastic strap, to the Greenland seal. Silver-silver chloride electrodes in small suction cups are placed in the vicinity of the heart to obtain a differential input. The system provides an excellent electrocardiogram. The record is free of drift and is uncluttered by extraneous signals representing muscle activity associated with swimming and breathing.

Surface detection of voltages associated with heart action in cetaceans was much easier to achieve than was expected originally on the basis of experience with man. The skin of these animals is unusually smooth, and the small suction cups prevent the shorting effect of the high conductivity of sea water. Bradycardia, or slowing of the heart rate, which occurs in all diving mammals investigated to date, including man, was demonstrated with the telemetry system. The instrument is suitable also for studies of fish when needle electrodes are substituted for surface electrodes.

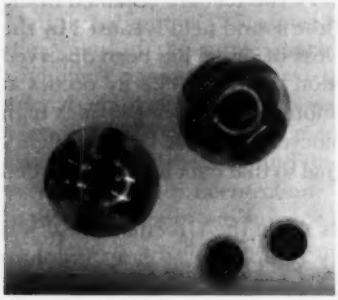
The EKG transmitter employs frequency modulation of a 50-kilocycle carrier. This modulation technique was selected to eliminate multipath propagation problems in the transmission of accurate analog data. A high impedance input circuit results in considerable reduction of the problems usually associated with surface movement of the electrodes on the body. Small mercury batteries provide about 8 hours of operating time at 70°F. Transmission ranges of 70 to 100 feet are obtained in the open sea, but considerable distortion of the sound field is caused by the high reflectivity of air in the lungs. No loss of signal has been observed in large tanks or aquaria where reflection of sound energy occurs at the sides of the enclosure. The companion FM receiver provides high gain and selectivity in the 45- to 55-kilocycle band. A beat-frequency oscillator is used to obtain an audible signal so that data may be recorded on magnetic tape.

Records were obtained for two hours while the Greenland seal was swimming freely in its tank, apparently completely at ease. Dolphins and some seals show an initial fear reaction when the ultrasonic transmitter is placed in their vicinity, but they seem to accept the device once they become accustomed to the ultrasonic signal.

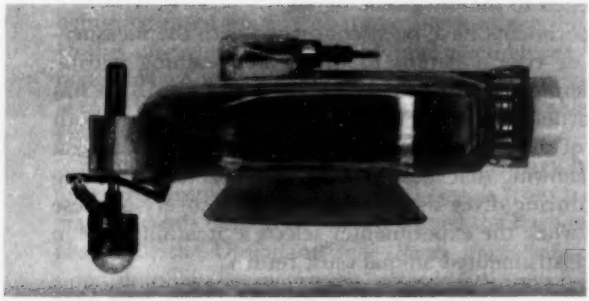
Several of our experiments have been concerned with the measurement of maximum or typical depths to which air-breathing marine animals dive. Mr. Gerald Kooyman of the University of Arizona has employed small recorders, 2-1/2 inches in diameter, to measure both the time and depth of dives of the Weddell seal in the antarctic. Data have been obtained showing that these animals are capable of reaching depths of 1428 feet during dives lasting 28 minutes. Recovery of these recorders is possible when the experimenter selects a breathing hole in the ice to which the instrumented animal must return.

Additional preliminary information on depths to which seals dive was obtained during the 1964-65 antarctic expedition with a small

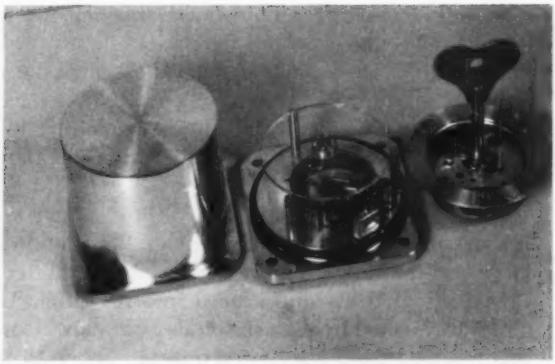
In a large tank about to be filled with water, a Greenland seal (*Phoca groendlandica*) awaits a study of heart action to be conducted while the animal swims freely. Measurements are obtained by an electrocardiogram transmitter, which is held in place on the seal by an elastic strap.



Neutrally buoyant transmitters designed to measure properties of fluid media. The larger spheres are less than an inch in diameter.



An instrument designed for the detection and transmission of sounds generated by dolphins. The spherical hydrophone is held in contact with the body of the animal by a suction cup. The unit is about 5 inches in length.



Components of an experimental depth-time recorder. The device was designed for attachment to the Weddell seal.

A remotely controlled ultrasonic receiver and syringe assembly are attached to a nurse shark in preparation for studies of olfaction.

ultrasonic transmitter. This device transmits an ultrasonic tone (45 to 55 kilocycles) that is proportional to the depth at which it is carried by an animal, and it enables one to track the animal during a dive by means of a directive hydrophone array. Some 50 dives have been recorded with this device, the deepest of which was to about 1000 feet. In another dive, the Weddell seal was tracked while swimming between breathing holes in the ice cap one mile apart.

Radio-frequency transmission through water and biological material is a valuable means of obtaining data when bandwidth requirements are large and the range required is low. A transmitter developed for use in dental research was introduced into the stomach of a 7-1/2-inch bass and was retained by the fish for about 2 hours. Continuous transmission was received from the device through about 14 inches of fresh water. The transmitter consisted of a radio-frequency oscillator (125 megacycles) operated with a single mercury cell. These devices weigh as little as 0.86 grams and transmit for about 5 days.

The preliminary experiments described here led to the design and construction of an FM radio-frequency transmitter for the detection and transmission of dolphin acoustic activity in studies of the animal's ability to communicate and echolocate. The transmitter unit, which is about 3 inches in diameter, adheres to the body of the dolphin (*Tursiops truncatus*) by means of a suction cup and thus allows the investigator to locate sources of sound energy on the surface of the body. Transmission from individual animals in the same enclosure may then be separated for acoustical and behavioral analysis. The transmission range in sea water at these frequencies is extremely limited (approximately one foot) and it is inversely proportional to the salinity of the medium. Signals can be obtained from the bottom of an 8-foot-deep fresh water pond with the same device.

The telemetry of environmental data is expected to be of value also in ecological studies. Preliminary efforts to design equipment for such studies have been directed to small neutrally buoyant transmitters for measurement of the properties of fluid media. These transmitters are contained in small spheres, about one inch in diameter. Our current investigation deals with an analysis of the accuracy with which such transmitters can be located in two dimensions in moving fluids. Similar units have been designed to monitor temperature and pressure in such an environment.

In summary, marine biotelemetry is an experimental technique that is only just beginning to receive recognition. It offers an unusual opportunity to conduct experiments in natural environments that should lead to a fuller understanding of the sensory and regulatory physiology of animal life. It should also give us the ability to monitor aquatic microenvironments of living systems without disturbing those characteristics which may be important.

A Navy plane skims low over ARLIS II. In the background is a row of the island's rocky hills..

ARLIS II Traverses Greenland Sea

ARLIS II, a drifting arctic ice island on which the Navy operates a scientific laboratory as part of its arctic research program, has begun an historic transit of the Greenland Sea. The ice island's course southward toward the Atlantic Ocean will permit the study of an area which surface ships have never penetrated in winter and only rarely in the summer months. As of February 12, the 3-1/2 mile long by 1-1/2 mile wide island was located at 78° 31.5′N. latitude and 8° 15′W. longitude, about midway between the northeastern coast of Greenland and the northwestern coast of Spitzbergen.

The scientific station is maintained and supported by the Office of Naval Research through the Arctic Research Laboratory, Point Barrow, Alaska, which is operated for ONR by the University of Alaska. Its normal complement is 12 to 15 scientists and support personnel. (See *Naval Research Reviews*, Sept. 1961 and Feb. 1963).

ARLIS II, which stands for Arctic Research Laboratory Island II, is a chunk of fresh-water (glacial) ice, from 40 to 80 feet thick, covered in many places with large piles of glacial debris.* It was discovered (or perhaps rediscovered, as an island answering its description was sighted on several occasions in the past, even by Admiral Peary in 1909) by Max Brewer, director of the Arctic Research Laboratory, in May 1961. The island was then drifting with the surrounding pack ice about 130 statute miles north of Point Barrow. Since then, it has followed a meandering path and is now about 1400 miles northeast of the point where it was first manned.

Even to the most discerning observer, ARLIS II looks remarkably like a snow-covered land mass. Its gently rolling topography differs markedly from the surrounding pack ice, whose perfectly flat surfaces alternate with heaps or ridges of blocky, broken ice. From "dunes" of glacial debris, the island's surface slopes gently downward to the pack ice of the ocean. At some places along the periphery of the island, the "coastline" is smooth like a beach, and in others, it is rugged, as the result of blocks of ice being pushed up on "shore". In the summer, a river, muddy with glacial silt and pebbles, cascades off the edge of the island to the pack. The piles of glacial debris, ranging in size from large boulders to fine silt, probably represent a terminal moraine that was deposited originally on some ice shelf in the Canadian north. These rock piles look very much like mountains, because of the faulty depth perception and lack of perspective which so commonly afflict observers in polar areas.

Only once before has a manned drifting ice station traversed the Greenland Sea. This station was the Russian NP-1, which made the trip in 1937-38 when instrumentation and techniques for making meteorological and oceanographic studies were primitive compared to those in use presently. NP-1 was an ice floe, which is smaller and less stable than an ice island. Only one other ice island has ever been inhabited by the United States for arctic research, and that one is Fletcher's Ice Island, or T-3, which is also operated by ARL for the Navy. It is now drifting between Point Barrow and ARLIS II. The Russians, who occupy two drift stations currently, NP-12 and NP-13, which are ice floes, have manned one ice island in the past.

The drift of ARLIS II through the Greenland Sea provides this country with the first opportunity to study in detail this relatively unknown geographic area. The Greenland Sea is particularly significant to the Navy, because it provides an important deep-water access route for submarines into the Arctic Ocean. It is also important scientifically,

*A discussion of the origin and structure of the island appears in the Journal of Glaciology, Vol. 5, No. 37, Feb. 1964. The report, entitled "Ice Lithologies and Structure of Ice Island ARLIS II," was prepared by David D. Smith on the basis of a study supported by ONR.

because it includes the broad transition zone where cold arctic waters and warmer Atlantic waters are known to mix.

Five research programs are in progress currently aboard ARLIS II. One program, conducted by the Naval Oceanographic Office as part of its ice prediction and forecast mission, involves the measurement of ice strain and ice formation and observations of the drift of pack ice. A program of geophysical investigations, including gravity measurements, is being carried out by the University of Wisconsin's Geophysical and Polar Research Center. A program in arctic marine biology, including the taxonomy and ecology of marine organisms, is being undertaken by the University of Southern California. Another program concerning meteorology and sea ice physics, in which surface weather observations are made on a three-hour schedule, and celestial navigation is applied to determine the daily geographic position of the station, is being conducted by the University of Washington. In addition, the University of Washington is now conducting a program for measuring currents. A team of Japanese oceanographers from Hokkaido University is engaged in studies in physical and chemical oceanography.

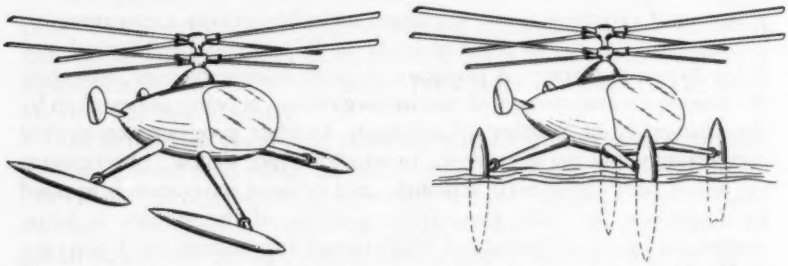
In addition to the above, two new programs are being activated on the station to exploit the drift through the Greenland Sea. These investigations will be of ocean-bottom heat flow and of a new, precise very low frequency (VLF) navigation system. More accurate information on the station's daily progress will be needed since ARLIS II is expected to move considerably faster than it has during its previous wanderings. The Russian NP-1 was reported to have traveled at an average speed of 20 miles per day during the latter part of its transit of the Greenland Sea. Based on the experience of NP-1, ARLIS II may have to be evacuated by April.

The basic mission of the Arctic Research Laboratory is to accomplish those programs of basic and applied research which contribute to successful Navy operations in arctic and sub-arctic regions. The temporary occupation of drift stations makes it possible to extend its research hundreds of miles into the Arctic Ocean Basin. For example, ARLIS II spent a period of its drift in the eastern hemisphere, which provided the Navy with its first opportunity for detailed studies in this region.

The fundamental knowledge of arctic environments that is being gained through this research will contribute to such Naval objectives as improvement of under-ice sonic and electromagnetic communications, navigation, detection and surveillance systems, including through-the-ice communications; the marking out of major access and egress routes for nuclear submarines in the Arctic Basin; improving methods of submarines surfacing through sea ice; developing techniques for construction on permafrost terrain; weather and ice forecasting; and gaining experience in naval operations in the arctic.

Inventions

Tilt Floats for Helicopters and Seaplanes



Views of an amphibious helicopter landing on the ocean with its floats in normal, horizontal position (left) and at rest on the water with its floats in vertical position (right).

The development of anti-submarine-warfare technology and the increased emphasis on air-sea rescue capabilities have pointed up the need for aircraft that can land upon the open sea and hold a stable position there while conducting operations.

While hovering, a helicopter is sufficiently stable to enable sonar gear suspended from it to function effectively and to enable people to be picked up from the water. However, in the process of holding a stable position, a large amount of fuel is consumed, thus limiting the range of the aircraft. Fuel consumption is reduced greatly, of course, if the helicopter lands on the water, but then the plane's stability is reduced by the action of the waves and wind, especially if the height of the waves is greater than 3 to 5 feet or the velocity of the wind is greater than 7 to 10 knots.

In view of these difficulties, Eugene H. Handler, of the Bureau of Naval Weapons, conceived a tilt-float pontoon system that enables a helicopter or seaplane to maintain good sea-keeping characteristics while floating on the ocean surface. The concept, disclosed in U.S Patent No. 2,973,169, provides for tiltable or retractable pontoons. Vertical positioning of the floats acts to minimize the effects of the wind and sea state upon the aircraft, thus allowing on-the-sea operation, which otherwise might not be possible.

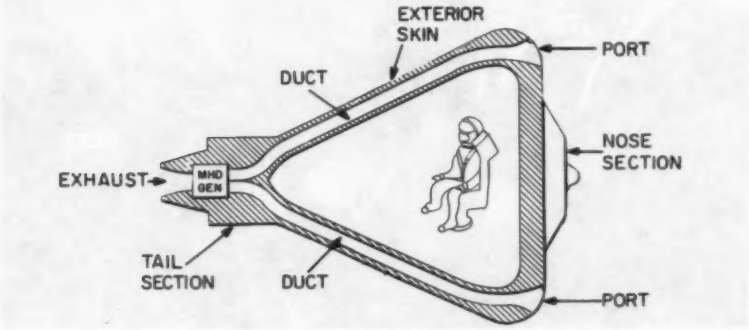
Operational tests of aircraft provided with tilt floats have been conducted in both the Atlantic and Pacific Oceans. A float-equipped DSNI helicopter tested by the Gyrodyne Company in Long Island Sound demonstrated good sea-keeping characteristics. On the Pacific coast, the sea-keeping characteristics of a PBM equipped with the floats was compared with those of a PBM not so equipped. The stability

of the plane riding on the new floats was so superior to that of the other plane that the Convair Corporation is now working toward the development of a float that is both retractable and inflatable.

Power Source for Spacecraft Reentry Operations

A simple, lightweight, efficient, and fail-safe power source intended to actuate instruments during the reentry into the atmosphere and the landing of a manned spacecraft has been invented by E. A. White, Jr., of the Naval Ordnance Laboratory, White Oak, Maryland. The invention bears U.S. Patent No. 3,156,433 and is entitled "Magnetohydrodynamic Generator."

For its operation, the magnetohydrodynamic generator utilizes the gas through which the spacecraft passes in the atmosphere. As the vehicle plummets earthward, the gas adjacent to it, particularly that flowing over the nose section, is heated and ionized. This ionized gas enters a number of ports back of the nose section, moves through a system of ducts, passes into the generator, and is exhausted finally at the tail of the vehicle. While passing through the duct system enroute to the generator, the gas is accelerated still further as a result of the proximity of the ducts to the outside skin of the vehicle, which is heated to a very high temperature by the flow of hot gases over it. Upon reaching the generator, the ionized gas passes an electrode and a magnetic field system, which cause the desired current to be produced.



Schematic view of a manned spacecraft, showing location of MHD generator, ports, and duct system. The invention is applicable to other spacecraft configurations also.

On the Naval Research Reserve

SIXTH NAVAL DISTRICT REPORTS

NRRC 6-6 Receives Award

On November 16, 1964, the first place plaque award for the Sixth Naval District for fiscal year 1964 was presented to Naval Reserve Research Company 6-6, Chapel Hill, N.C., by CAPT R. W. Warner, USN, head of the Department of Naval Science at the University of North Carolina. During the competition period every officer in the 31-member unit earned a satisfactory year of Federal service, and 65 percent of the membership participated in active duty for training.

CDR Marvin E. Woodard, USNR (left), immediate past commanding officer, NRRC 6-6, receives the Sixth Naval District award from CAPT Warner (right). Other officers shown are CDR W. A. Stockdale, USNR (second from left), commanding officer, Naval Reserve Training Center, Durham, N.C.; LCDR Adger Wilson, USNR (center), present commanding officer, NRRC 6-6; and CDR F. H. Langdon, USNR (second from right), Fifth and Sixth Naval District Research Reserve liaison officer.

Research Reservist Honored

LCDR Glenn M. Gray, USNR-R, a member of Naval Reserve Research Company 6-1, Atlanta, Georgia, was honored in September by the Society of Experimental Test Pilots at its national convention in Los Angeles, California. He was awarded the plaque for the most outstanding paper, entitled "The Progress of the XV-4A Hummingbird," presented at the meeting. In civilian life LCDR Gray is employed by the Lockheed-Georgia Company, where he has been the test pilot of the experimental "Hummingbird" aircraft, a vertical take-off and landing vehicle.

LCDR Gray, of NRRC 6-1, displays his award.

15th Annual Nuclear Sciences Seminar

The Fifteenth Annual ONR Nuclear Sciences Seminar was held at Oak Ridge, Tennessee, November 30 through December 11, 1964, with Naval Reserve Research Company 6-3 serving as the host. The seminar was sponsored by the Office of Naval Research in conjunction with the Atomic Energy Commission and the Oak Ridge National Laboratory. The 57 participants included 45 Naval Reserve and 12 Army Reserve officers. LCDR James N. Robinson, USNR, served as seminar chairman.

The seminar was opened officially with welcoming remarks by LCDR Robinson. Greetings from the commandant of the Sixth Naval District

were extended by CDR J. A. Scholes, USN, executive officer, NROTC Unit, Vanderbilt University. CAPT L. B. Melson, USN, director, Naval Applications Group, ONR, reviewed recent significant Naval research and development accomplishments. In addition, he gave an illustrated presentation on the Navy's SEALAB I underwater experiment. Other opening-session talks were given by Dr. R. B. Martin, representing the manager of the Oak Ridge Operations Office, USAEC, and Dr. W. G. Pollard, executive director, Oak Ridge Institute of Nuclear Studies.

During the two-week seminar, discussions were devoted to various phases of the overall nuclear research program, including basic theory and applications in the field of nuclear energy, the life sciences, the use of isotopes, and the development of nuclear reactors for military, space, experimental, and power uses. The lectures were given by scientists and engineers associated with the Oak Ridge National Laboratory, the Oak Ridge Institute of Nuclear Studies, the University of Tennessee-AEC Agriculture Research Facility, and military speakers.

Military speakers and the subjects of their presentations were as follows: "The Research Reserve Program," by CAPT D. J. Mooney, Jr., USNR, Special Assistant to the Chief of Naval Research (Research Reserve); "Nuclear Weapons," by CDR Glenwood Clark, Jr., USN, Headquarters, Defense Atomic Support Agency, Research Division, Department of Defense; "Air Force Nuclear Power Program," by CAPT H. M. Mitchell, USAF, Nuclear Power Division, Headquarters, U.S. Air Force; "Army Nuclear Power Program," by LT COL E. J. Denz, USA, Office of the Chief of Engineers, U.S. Army; "The Polaris Submarine Program," by CAPT J. K. Leasure, USNR; and "Promotion-Retirement Attrition," by CDR R. D. Marion, USNR, officer in charge, U.S. Naval Reserve Recording Activity.

Field Trips were made to the University of Tennessee-AEC Large Animal Irradiation Facility, the Bull Run Steam Plant, and the Oak Ridge National Laboratory. At the Oak Ridge National Laboratory, the group visited the Biology Division Laboratory, the Tower Shielding Facility, the Homogeneous Reactor, the Molten Salt Reactor Experiment, the High Flux Intensity Reactor and Transuranium Facility, the Experimental Gas Cooled Reactor, the Oak Ridge Isochronous Cyclotron, the High Radiation Level Examination Laboratory, and the Oak Ridge Research Reactor.

Glassmaking Plant Visited

Members of Naval Reserve Research Company 6-18 observed the "last word" in technical research and development in the glassmaking industry during their visit to the Ford Motor Company Glass Plant in

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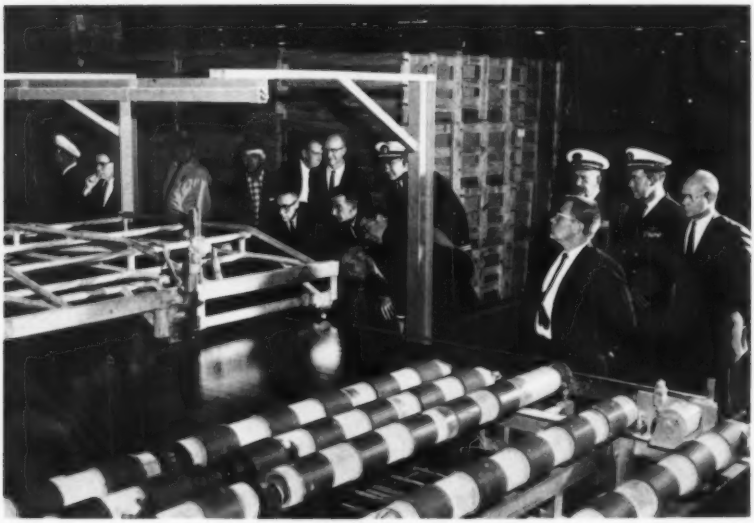

Members of NRRC 6-18 observe glassmaking during field trip.

Nashville, Tennessee, on November 2, 1964. The officers were treated to a glimpse into the future in the largest automotive-glass-producing plant in the world. Particularly impressive were the demonstrations of technological developments that have been achieved in safety glass for automobile windshields.

CDR Ned L. Warren, USNR, is the commanding officer of NRRC 6-18, which recently received the Sixth Naval District second place award for Naval Reserve Research companies for fiscal year 1964.

NRRC 6-3 Visits RIDL

On November 18, 1964, members of Naval Reserve Research Company 6-3, Oak Ridge, Tennessee, visited the Ridge Instrument Development Laboratory, where they were shown the latest electronic analyzers and counting instrumentation. Since this unit was established in 1949, it has been interested actively in the nuclear sciences. This interest has been expressed through the company's organization of the first emergency radiological defense squad in the southeastern area, in 1950, and through its sponsorship of annual seminars covering current developments in the nuclear sciences.

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Messages delivered by voice—still the most common means of communication in the military services—often fail to "get through" because of the speaking and listening practices of the communicators. The author discusses the problem and a solution to it.

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Ways of overcoming difficulties that have been experienced in obtaining information on the activities of marine animals in their natural environment are explored in this discussion of the telemetering of of physiological data from subject to investigator.

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An ice island manned by scientists is moving from the Arctic Ocean into the North Atlantic. The "voyage" will enable the scientists to explore a new region, but it will also bring about the "island's" disintegration.

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EDITOR: Richard D. Olson

NAVSO P-510

A new decay mode of an extremely rare elementary particle, known as the Omega-minus, was discovered recently by the Nucleonics Division of the Naval Research Laboratory in collaboration with the University of Maryland. The negatively charged Omega particle had been observed only three times before. Shown on the front cover is a photograph and an explanatory sketch depicting the new decay mode of Omega-minus. The path of the incident beam particle is labeled (1); that of the new Omega particle is labeled (3). Omega-minus (Ω^-) is produced by an interaction of particle 1 with a proton in the hydrogen bubble chamber along with particle 2 (a positve K-meson, K^+) and a neutral K-meson, K^o, which decays into particles 6 and 7. The Omega particle decays shortly thereafter into particle 4 (a Xi-hyperon) and a neutral pion. The Xi-hyperon decays in turn into particle 5 and a Lambda-hyperon (λ). The Lambda-hyperon then decays into particles 8 and 9, a proton and a negative Pi-meson, respectively.